What would you, could you, do with wood?

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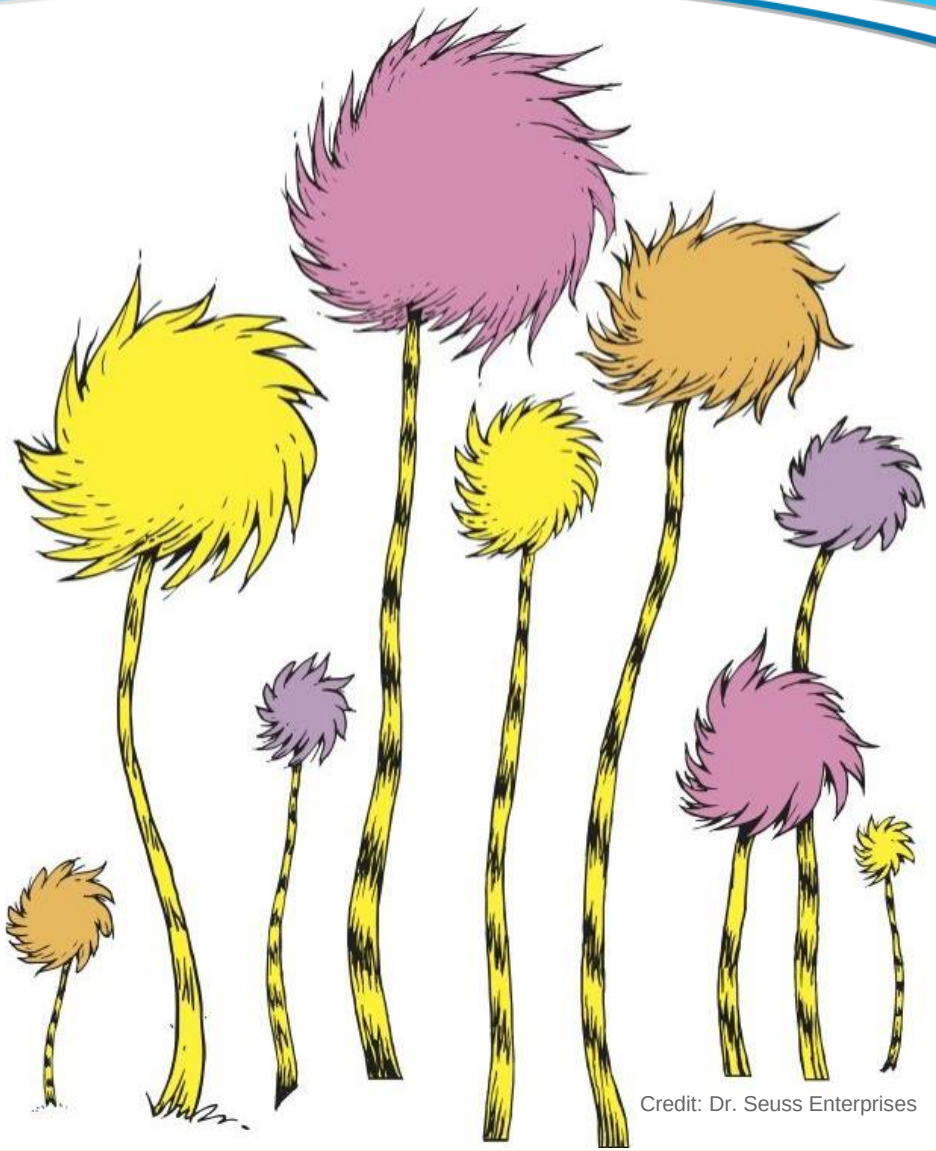
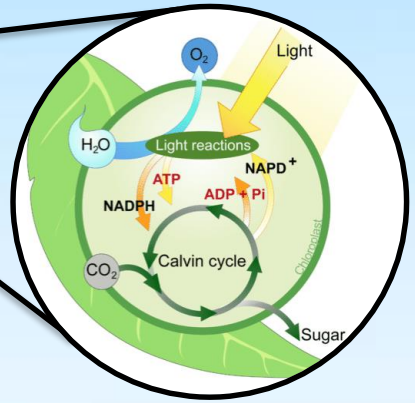
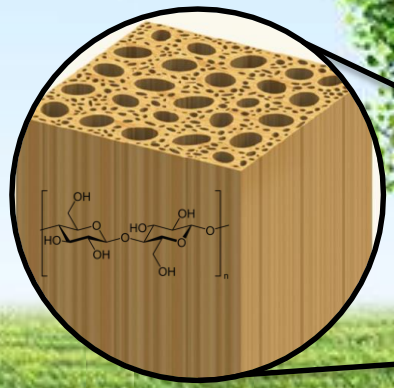


Credit: Dr. Seuss Enterprises

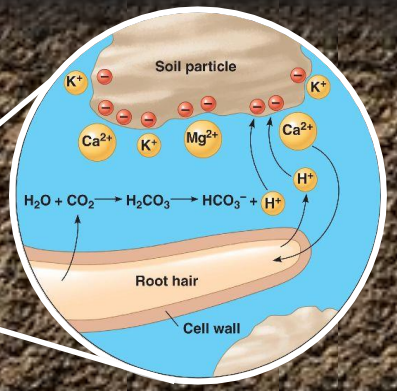
Direct Air Capture (DAC)





Carbon Storage in a multifunctional material

Soil Carbon Sequestration and Microbiome Interactions



Mass Transport Network

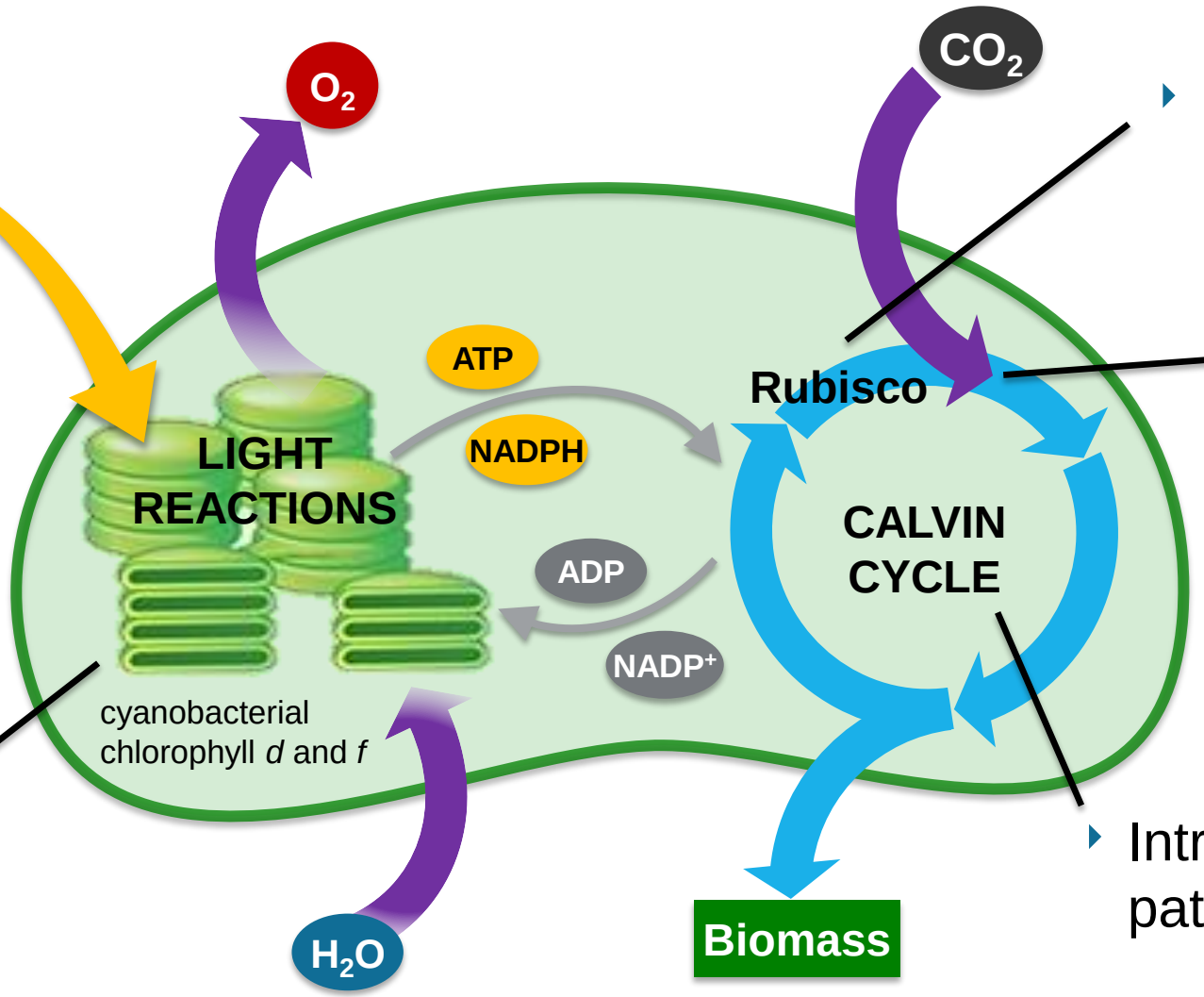
How can we increase the carbon-sequestration potential of trees and forests?

- Increase atmospheric carbon uptake
- Allocate carbon preferentially into high value solid form
- Improve growth rate
- Forest placement (arid, degraded land, etc.)

Maximizing CO_2 Uptake and Assimilation

- Improve light capture by engineering leaf architecture.

- Extend the waveband of light available for photosynthesis.



- Improve Rubisco kinetic properties.
- Enhance CO_2 concentrating mechanisms and redesign photo-respiration.
- Introduce the C_4 pathway into C_3 trees.

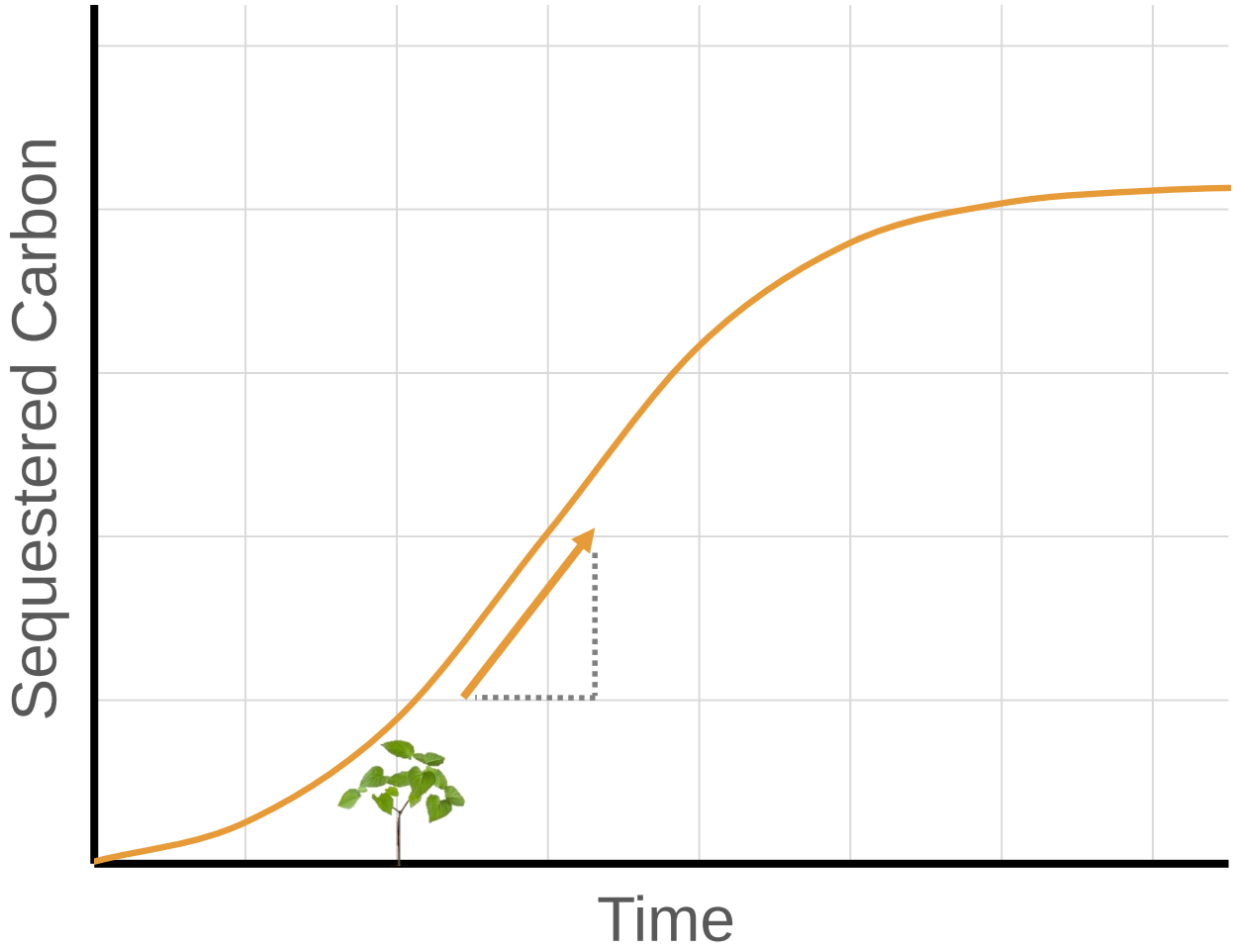
Reference: Evans, John. Improving Photosynthesis. *Plant Physiology.* **162**, 1780-1793 (2013).

Increasing Carbon Transport and Allocation

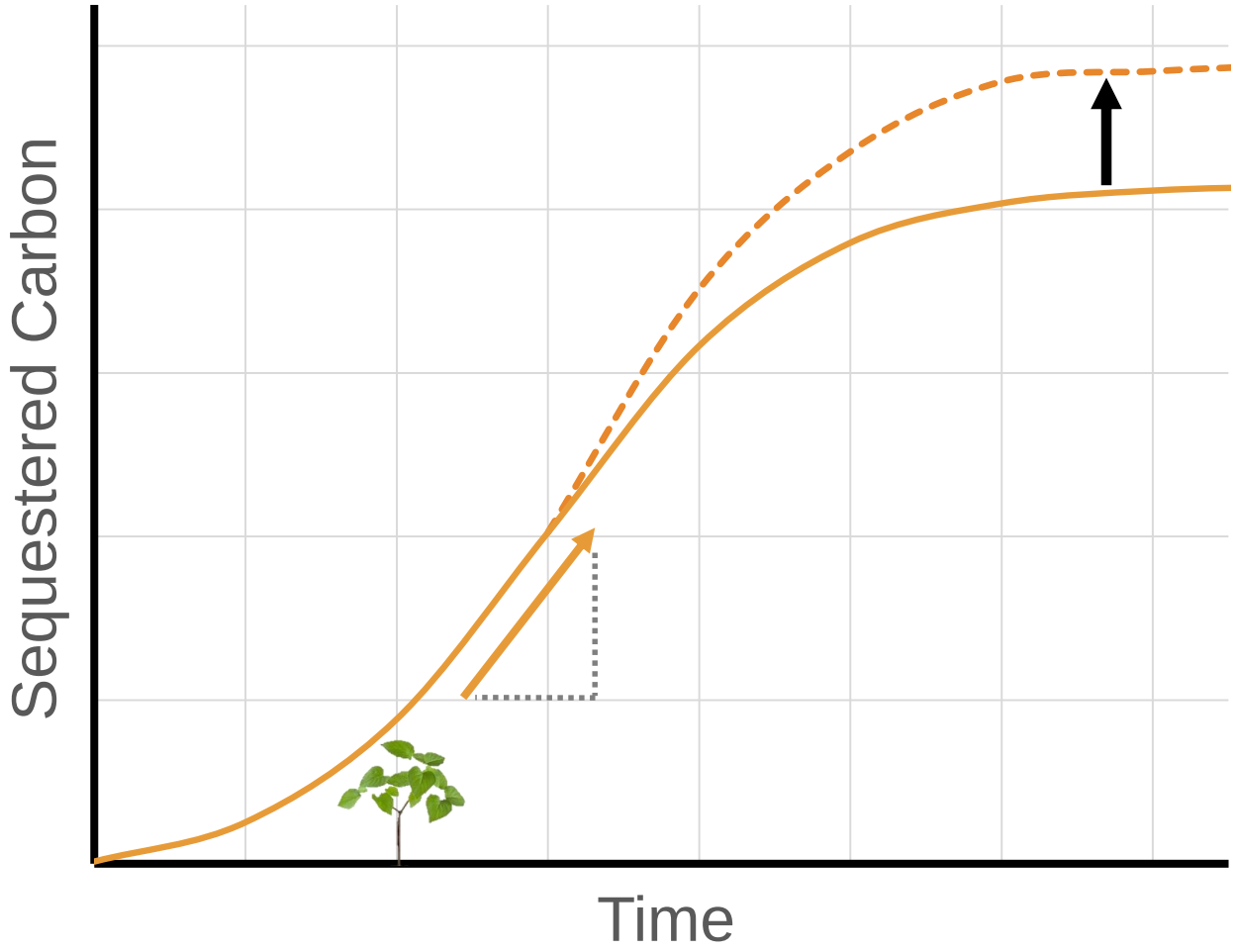
- Improve the allocation of carbon to the woody biomass portion of the tree by modifying genes regulating:
  - Tree height, thickness, and dominance of the central stem (v. branching).
  - Biomass density through the biosynthesis and deposition of cellulose, lignin, and other carbon-based polymers.
- Can we apply synthetic biology techniques to accelerate tree engineering?

Reference: Dubouzet et al. Potential transgenic routes to increase tree biomass. *Plant Sci.* **212**, 72-101 (2013).

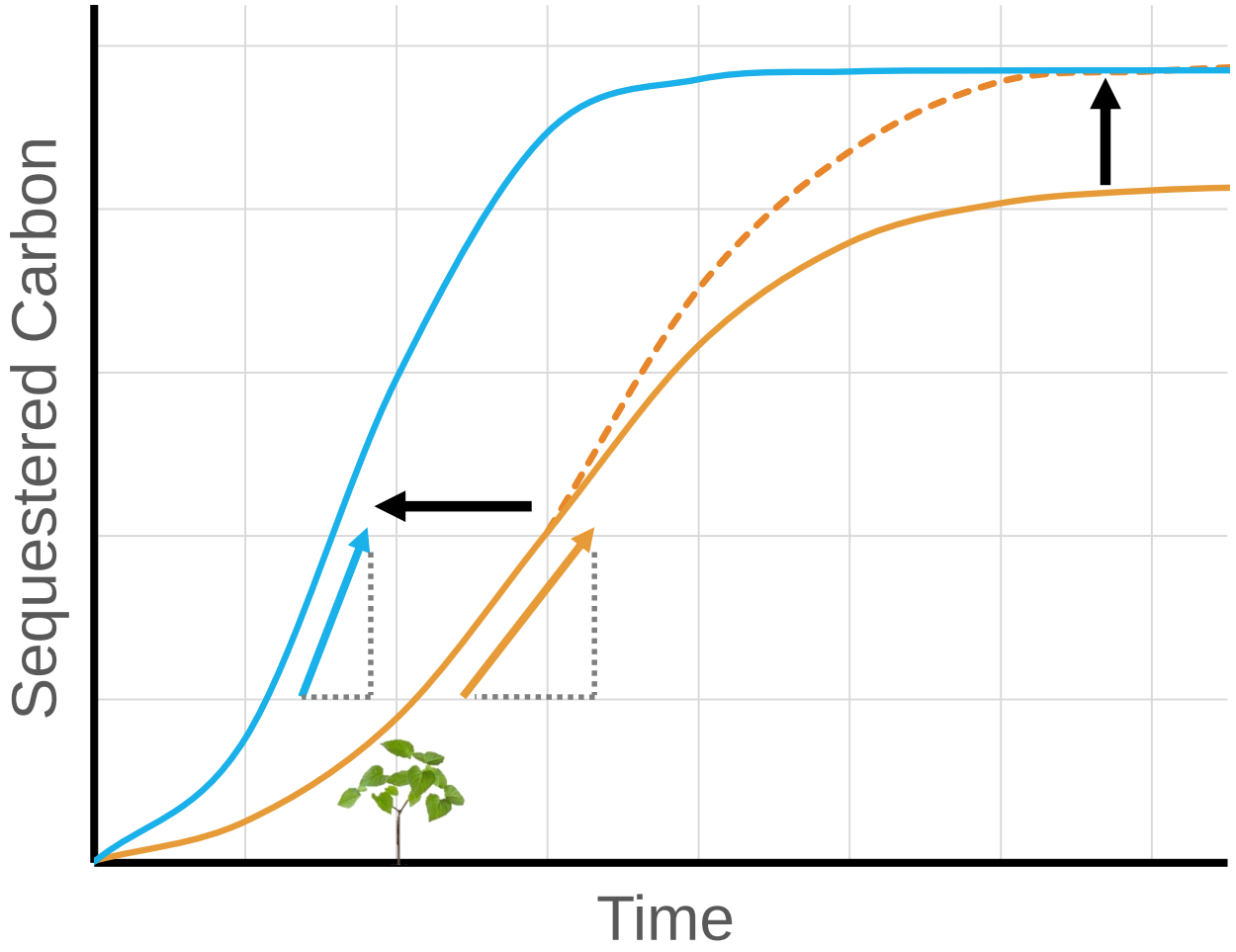
Affecting the Growth Rate of a Tree



Affecting the Growth Rate of a Tree



Affecting the Growth Rate of a Tree

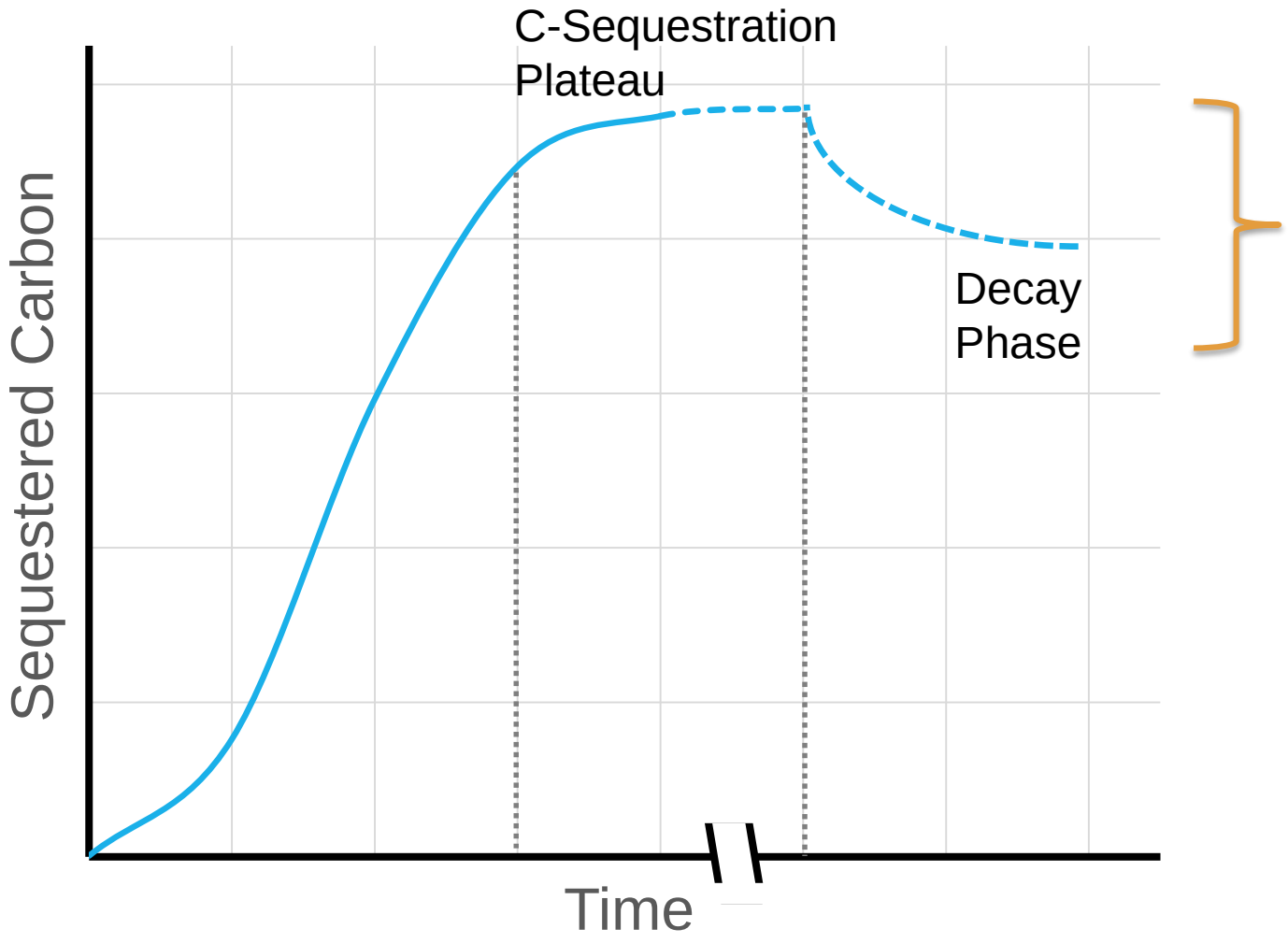


- Can we use genetics to grow an oak tree at the rate of bamboo?
- Poplar tree genes PXY and CLE control outward growth in the tree trunk.
  - Over-expression resulted in a 2x increase in growth rate.
- What are corresponding genes affecting growth rate in other species, and can they be modified?
- Can we engineer trees to grow on degraded, desertified, and nutrient depleted land?

Reference: Etchells et al. Wood Formation in Trees Is Increased by Manipulating PXY-Regulated Cell Division. *Curr Biol.* **25**(8) 1050-1055 (2015).

Once carbon is captured and converted into woody biomass, how can we ensure that it stays sequestered?

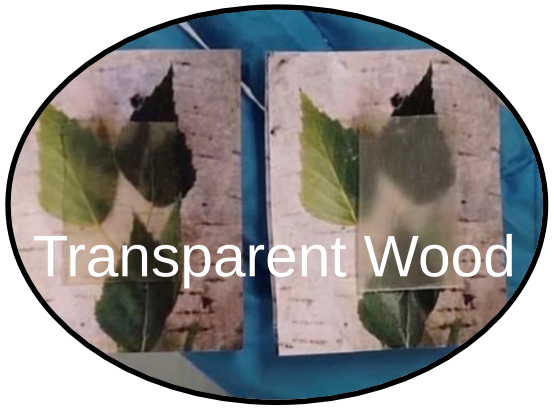
Ensuring that Carbon stays Sequestered



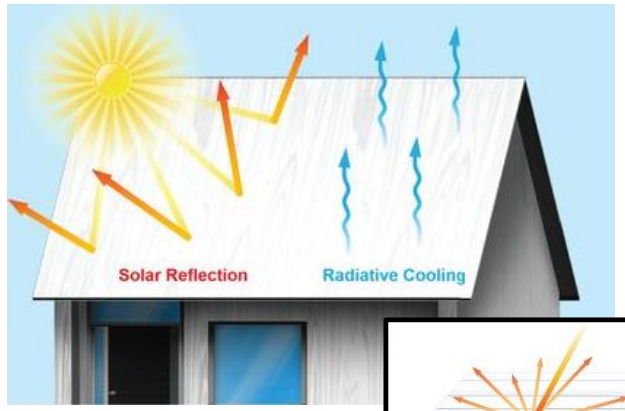
- Look at mitigating biomass decomposition to CO_2 (often a decadal process)
  - Understand and engineer the soil microbiome
- **Convert mature trees into long-lived carbon-rich materials**

Putting Wood to Work

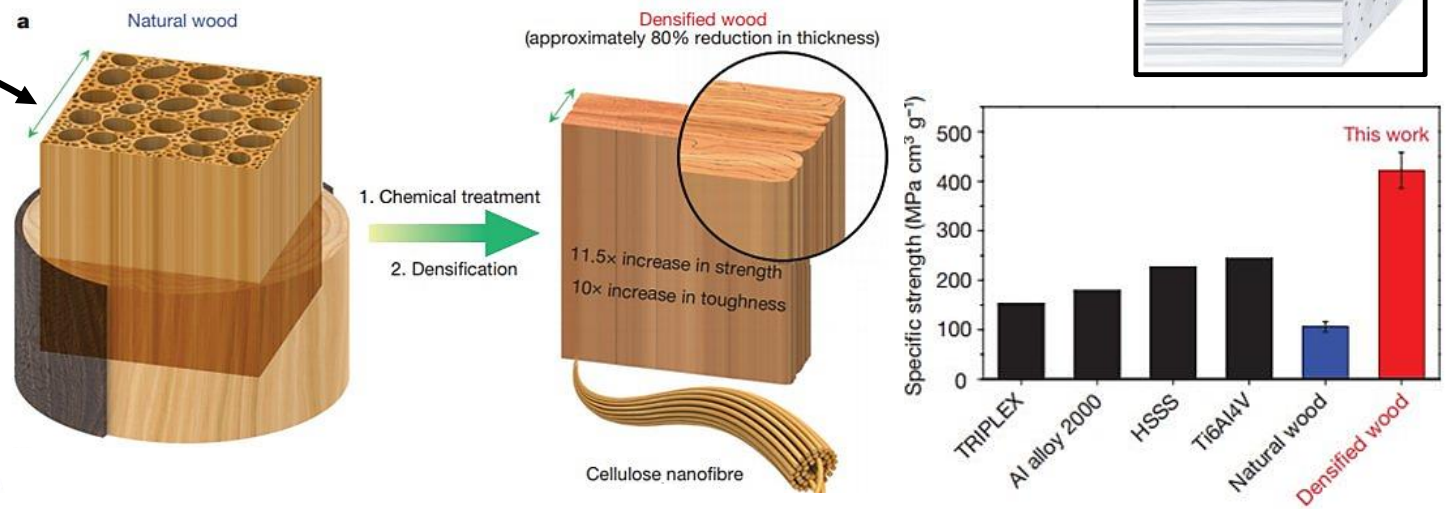
- Mass Timber Construction



Radiative cooling wood



Super high strength densified wood



Sources: Sathre et al. A Synthesis of Research on Wood Products and Greenhouse Gas Impacts, 2nd Edition. *FPInnovations.* Technical Report TR-19R (2010).
https://phys.org/news/2019-04-transparent-wood.html
Song et al. Processing bulk natural wood into a high-performance structural material. *Nature.* **554**, 24–228 (2018).
Li et al. A radiative cooling structural material. *Science.* **364**(6442), 760-763 (2019).

From a Super Tree to a Super Carbon Sink

- Net Carbon Sequestered = *f*(tree genetics) × *f*(environmental interactions)

- How can we improve biology to maximize forest carbon sequestration?
- How can we ensure carbon stays sequestered?
    - Identifying next-generation wood-based products
    - Achieve complete utilization of wood components

Your input is key!

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Credit: Dr. Seuss Enterprises